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Effect of solid thermal conductivity and particle–particle contact on effective thermodiffusion coefficient in porous media

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ABSTRACT

Transient mass transfer associated to a thermal gradient through a saturated porous medium is studied experimentally and theoretically to determine the effect of solid thermal conductivity and particle–particle contact on thermodiffusion processes. In this study, the theoretical volume averaging model developed in a previous study has been adopted to determine the effective transport coefficients in the case of particle–particle contact configurations. The theoretical results revealed that the effective thermodiffusion coefficient is independent of the thermal conductivity ratio for pure diffusive cases. In all cases, even if the effective thermal conductivity depends on the particle–particle contact, the effective thermodiffusion coefficient remains independent of the solid phase connectivity. We also found that the porosity can change the impact of dispersion effects on the thermodiffusion coefficients. For large values of the thermal conductivity contrast, dispersion effects are negligible and the effective thermal conductivity coefficients are the same as the ones for the pure diffusion case.

Experimental results obtained for the purely diffusive case, using a special two-bulb apparatus, confirm the theoretical results. These results also show that, for non-consolidated porous media made of spheres, the thermal conductivity ratio has no significant influence on the thermodiffusion process for pure diffusion. Finally, the particle–particle contact also does not show a considerable influence on the thermodiffusion process.

1. Introduction

In many situations involving multi-component fluids mixture, the presence of thermal gradient can be the cause of species migration because of the phenomenon known as Soret effect or thermodiffusion [25,41]. The applications of thermodiffusion in free fluid as well as in porous media become more and more important nowadays in industrial such as isotope separation in liquid and gaseous mixtures [33,34], polymer solutions and colloidal dispersions [45], study of compositional variation in hydrocarbon reservoirs [12], coating of metallic items, solidifying metallic alloys, migration of the DNA molecules [3,23], volcanic lava, transport in the Earth Mantle [19], etc.

Many works have been carried out to determine thermodiffusion coefficients using different approaches. Experimental approaches have been developed for instance using a two-bulb method in the case of a free medium (Ibbs and Chapman, 1921 [18]; Heath et al., 1941 [16]; van Itterbeek et al., 1947 [43]; Mason et al., 1964 [26]; Saxena et al., 1966 [38]; Humphreys and Gray, 1970 [17]; Grew and Wakeham, 1971 [15]; Shashkov et al., 1979 [40] and Zhdanov et al., 1980 [46]). Soret coefficients have also been determined in crude oils under microgravity condition [14,42] or thermogravitational column [29]. Theoretical approaches have also been used like molecular dynamics simulations [13,35] or multi-component numerical models [36].

While the transfer of species related to thermodiffusion in porous media may directly be linked to the physical and thermal properties of the solid structures, various theoretical studies had generally treated this problem considering the whole system as an equivalent continuum (macroscopic approach) [1,21]. Failures in the thermogravitational models [11] based on the free fluid equations are a good example of the need to determine the influence of the thermo-physical properties of the pore matrix on the thermodiffusion process in porous media.

Additionally, one of the most important features that has not really been taken into account is the existing difference in thermal conductivity between the solid matrix and the fluid phase.

The evaluation of the influence of the porosity and tortuosity on the thermodiffusion coefficients has been the object of many researches:

- Experimental studies: Platten and Costesèque (2004), using a thermogravitational column [29]; Costesèque et al. (2004), using

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